Normative modeling of auditory memory for natural sounds

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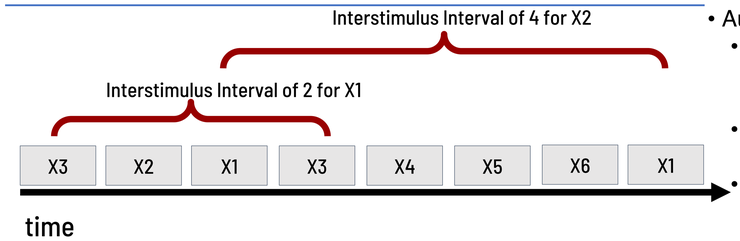
Introduction

- Auditory memory is integral to everyday life, but underlying representations remain poorly understood
- **Goal: develop a normative account of memory of actual sensory signals**
- Further understand:
  - why some sounds are forgettable and some are memorable,
  - why false memories occur,
  - and why memory is the way it is.

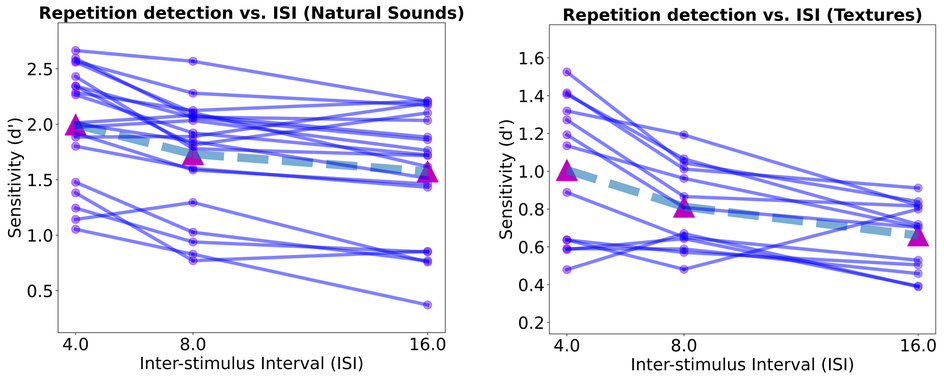
Psychophysical Methods



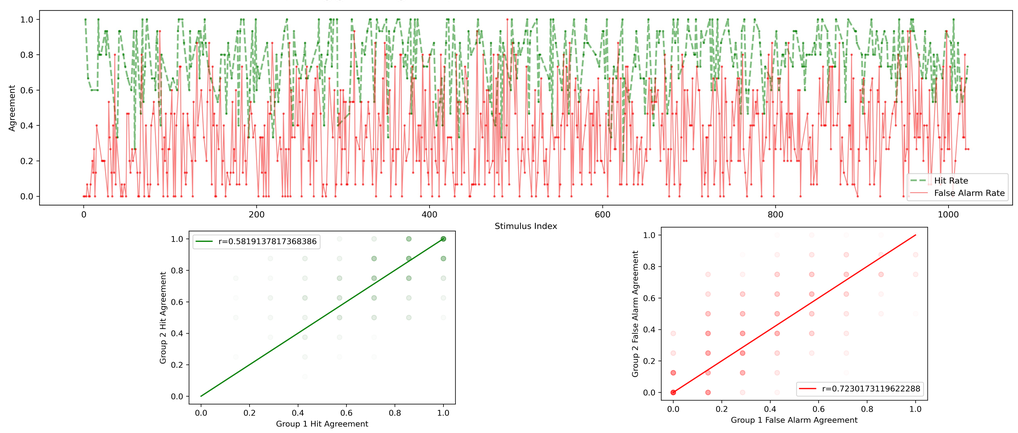
- Auditory memory experiment:
  - 2 second clips of natural auditory scenes, serially presented
  - Some clips repeat within experiment, some don't
  - After each presentation, participant asked if clip was heard before in the experiment
- Main experimental parameter:
  - Interstimulus Interval (ISI); number of intervening stimuli between a first presentation and its repetition

Psychophysical Results

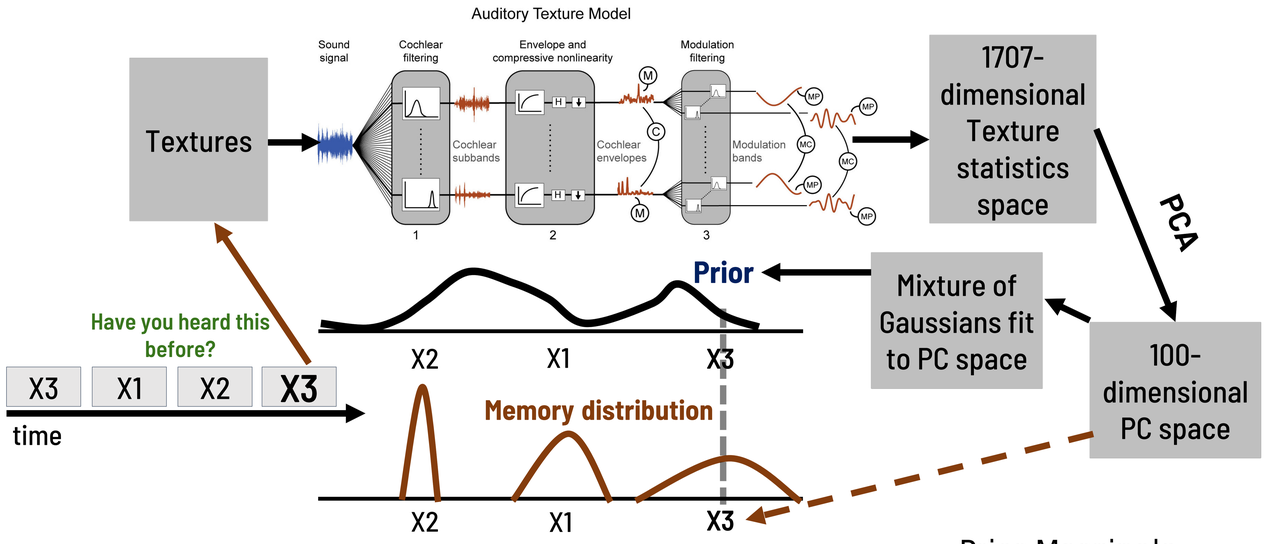
- In an experiment where clips can only repeat at most once, performance decreases as the interstimulus interval increases.
- Repeated experiment with auditory textures.
- Performance trends consistent across both experiments



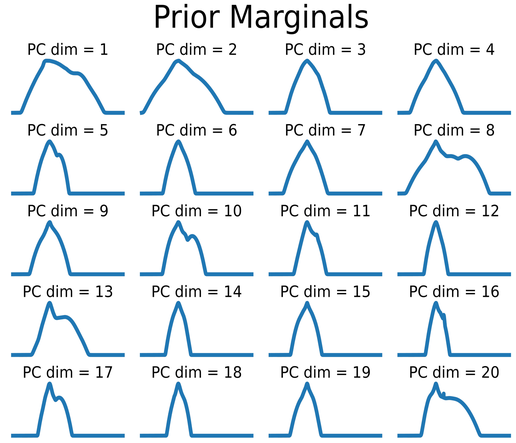
- When multiple participants viewed same stimulus sequence, there is agreement on hits and false alarms, suggesting responses are not random



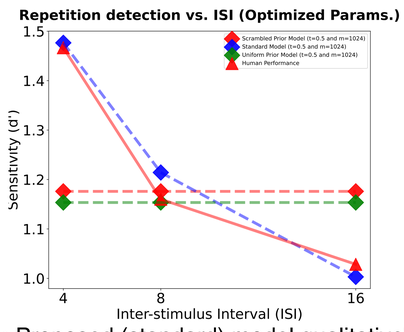
Ideal Observer Methods

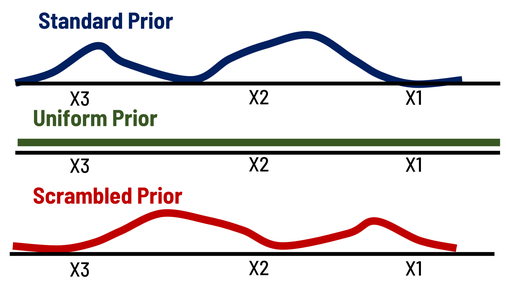


- Ideal observer model encodes experiences as memory traces whose noise grows with time
- Observer decides whether a subsequent stimulus is more likely to have come from the distribution of stimuli implied by these memory traces or from the prior distribution over all textures.
- Memory traces assumed to be based on texture statistics of heard stimulus
- ~143,000 textures from natural auditory scenes (obtained from the AudioSet dataset).
- Ideal observer is assumed to have knowledge of how noise in a trace grows with time. The memory traces are thus associated with a distribution of experiences, modeled as a mixture of Gaussians in the space of texture statistics.
- The prior is modeled as a mixture of Gaussians fit to the principal components of the statistics of a large set of natural textures.



Ideal Observer Results





- To determine necessity of prior for replicating human judgments, proposed model is compared to models with alternative priors:
  - Uniform prior over texture statistics
  - "Scrambled" priors with shuffled means and covariances
- Proposed (standard) model qualitatively mirrors human trends on the same task, while alternative models do not.
- Suggests that humans have internalized a prior over stimulus statistics in memory and use that to make memory judgments

Future work

- Observe and model the effects that number of stimulus repetitions has on humans recognition performance
- Use model to predict human judgments on a trial by trial basis
- Use recent advances in deep neural networks to obtain a representation for all natural sounds, and not just auditory textures